



Antibiotic Resistance Profiles of *Lactobacillus* spp. from Animal and Food Ecosystems

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ABSTRACT

Due to the extensive and frequent careless use of antibiotics in human, veterinary, and agricultural settings, antibiotic resistance (AR) has become one of the biggest risks to worldwide public health. Lactic acid bacteria (LAB), especially *Lactobacillus* species, are crucial for probiotic uses, animal nutrition, and food fermentation. Recent research suggests that *Lactobacillus* strains from animal and food environments may have innate and acquired antibiotic resistance genes (ARGs), despite their long history of safe use. This raises concerns about their safety. With an emphasis on resistance to aminoglycosides, macrolides, tetracyclines, fluoroquinolones, β -lactams, and vancomycin, this review outlines the prevalence, phenotypic characteristics, and genotypic drivers of AR in *Lactobacillus* species isolated from animals and food products. Numerous ARGs in *Lactobacillus* species are linked with mobile genetic elements, indicating the possibility of horizontal gene transfer to other beneficial and pathogenic microorganisms in the food chain and gastrointestinal tract. Acquired resistance poses a serious risk for the spread of ARGs, but intrinsic resistance in *Lactobacillus* (such as to vancomycin and aminoglycosides) is typically regarded as non-transferable and of low safety concern. Because *Lactobacillus* strains are widely used in food and probiotic compositions, strain selection should incorporate thorough safety evaluation, including phenotypic and molecular AR profiling, before commercialization. To prevent the emergence of resistance and protect public health and food safety, it is crucial to continuously monitor AR trends in animal and food-associated *Lactobacillus* spp.

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INTRODUCTION

A rising global concern, antibiotic resistance affects not only the microbiological safety and overall quality of food items but also the health of animals and humans (Floris et al, 2025). The worldwide health situation is being negatively impacted by the antibiotic resistance dilemma, which has escalated dramatically over the last century. Drug resistance has existed from the beginning of the antibiotic period, even throughout the penicillin era (Das et al, 2020), and the World Health Organization currently ranks it as one of the top 10 worldwide public health problems (Kwon and Powderly, 2021; Tian et al, 2025). Basically, antibiotic resistance is a bacterial adaptation. However, due to the overuse and careless application of antibiotics, selective pressure has increased, causing bacterial evolutionary responses to environmental pressures and a rise in resistance rates (Vikesland et al, 2019; Colautti

et al, 2022). The inappropriate use of antibiotics occurs at higher rates in animal agriculture sector (Van Boeckel et al, 2019). Antibiotics have been utilized extensively in fields relating to poultry and livestock production for many years. They are frequently employed as antimicrobial growth promoters and to prevent or treat bacterial infections (Al-Khalaifa et al, 2019).

Antibiotics, whether naturally derived, synthetic or semi-synthetic in origin, work by inhibiting the growth of or eradicating the bacterial populations, thereby having a great role in prevention and resolution of bacterial infections. However, the widespread use of these agents has driven the global rise and spread of multidrug resistant (MDR) microbes. Projections indicate that if the current trajectory of MDR bacterial evolution continues, the mortality rate due to the infections associated with resistant bacteria will surpass that of cancer by 2050 (Abreu et al, 2023).

Antibiotics exert selection pressure on indigenous microflora and target pathogens when they are administered because of their loose pathogen specificity, which causes the evolution of resistant strains. This implies that numerous commensal strains will unavoidably develop resistance to the antibiotic treatment that targets a particular bacterial disease. This mechanism produces resistant commensals, which are important sources of genes that confer resistance to antibiotics (Juricova et al, 2021).

Probiotic supplementation is now seen as an alternate approach to infection prevention and therapy. Antibiotic use may be reduced by using probiotic products as a preventative measure. Gut microbiota is not adversely affected by probiotics (HM and Kotb 2021). A probiotic is defined by the World Health Organization (WHO) and the Food and Agriculture Organization of UN (FAO) as "live microorganisms that, when taken in sufficient quantities, exert beneficial effects on the host's health." Probiotics are of great importance because of their two main advantages: boosting the immunity and enhancing the activity of gastrointestinal tract (Zolfaghari et al, 2025).

Lactic acid bacteria (LAB) are often used as probiotic microorganisms and can be found in fermented food items in the GIT of animals and humans (Mandal et al, 2021). Lactic acid bacteria (LAB) is one of the types of bacteria that produce lactic acid as a metabolic product. Leading genera of LAB include *Lactobacillus*, *Streptococcus*, *Propionibacterium*, *Pediococcus*, *Bifidobacterium*, *Lactococcus* and *Leuconostoc*. They may have certain health benefits, and due to these potential health benefits, some periodically refer to them as probiotics and are generally considered harmless (Adeniyi et al, 2024). *Lactobacillus* is the most common and largest genus of LAB, and is extensively used in fermented foods, i.e, dairy and meat products. Various *Lactobacillus* strains are used to assist animals and humans digest food and absorb nutrients at an increased rate (Zommiti et al, 2020; Ojha et al, 2021). Over 300 *Lactobacillus* species (25 genera) are found in human, animal, and plant microbiomes and are useful in agriculture, food systems, and medicine (Mejía-Caballero and Marco, 2025).

Because of their extensive history of safe and technical application, it is likely that *Lactobacillus* strains are the most frequently used as probiotics and starter cultures, both in agriculture and industry (Devirgiliis et al, 2013; Xu et al, 2024). Although lactobacilli are of great economic importance, the issue of lactobacilli safety has not been of much concern. It been reported that lactobacilli may also cause bacteremia, endocarditis, and other opportunistic infections (Rossi et al, 2022). The second big concern is that certain *Lactobacillus* species have acquired resistance to key human and veterinary antibiotics (Devirgiliis et al, 2011, Stefańska et al, 2021). However, they are not pathogenic; therefore, they can potentially act as reservoirs of antibiotic resistance genes (ARGs) that can then be transferred to other gastrointestinal bacterial species (Campedelli et al, 2019). *Lactobacillus* species are said to be naturally (by nature) resistant to various classes of antibiotics, such as glycopeptides, folate synthesis inhibitors, aminoglycosides, nucleic acid synthesis inhibitors, among others (Kerek et al, 2024).

Acquired resistance in lactobacilli can pose a risk to food and nutritional supplements containing probiotic strains

(Zavišić et al, 2023). It is believed that the main route through which antibiotic resistant (AR) bacteria of the environment and animals enter the human digestive system is the food chain (Rossi et al, 2014, Thumu and Halami, 2019). It has been demonstrated that lactobacilli have the ability to transfer its resistance to other bacterial species in both in vivo and in vitro studies (Nawaz et al, 2011; Anisimova et al, 2022). In order to ensure that the effects are positive, it seems important to implement AR testing into the safety assessment of any probiotic and food product prior to its launch onto the market (Aggarwal et al, 2022; Zavišić et al, 2023). In order to assess the propagation of resistant strains and resistance determinants in different ecosystems, antibiotic resistance should be monitored (Dec et al, 2020). Thus, this paper performed a critical literature review on prevalence and trends of antibiotic resistance in *Lactobacillus* strains present in food and veterinary ecosystems, the safety of these strains as probiotics, and the potential role of such strains in the transmission of antibiotic resistance in diverse ecosystems.

Genus *Lactobacillus* and its Significance

One of the first to be classified as a bacterial group is lactobacilli, their taxonomy has been redefined several times since the original description of the genus *Lactobacillus* by Beijerinck in 1901 (Zheng et al, 2020). They are non-sporing, non-motile, catalase-negative and Gram-positive rod-shaped bacteria, although coccobacillary forms do exist. They live in a high-nutrient environment that contains animals, people, food, plants, soil, and feed (Duar et al, 2017, Salvetti et al, 2018, Seneviratne et al, 2023), and are usually categorized into three groups based on their metabolic activity (Coelho et al, 2022).

Obligately Homofermentative

These lactobacilli yield lactic acid as a metabolic product as a result of carbohydrate fermentation (e.g. *L. amylovarus* and *L. johnsonii*).

Facultatively Heterofermentative

These lactobacilli, with specific substrates and conditions, ferment carbohydrates and release lactic acid, carbon dioxide, and acetic acid/ethanol (e.g. *L. rhamnosus*, *L. casei*, *L. plantarum*).

Obligately Heterofermentative

This group comprises the *Lactobacillus* spp. that consistently ferment carbohydrates and yield lactic acid, acetic acid/ethanol, and carbon dioxide (e.g. *L. fermentum*, *L. ruteri*) (Dempsey and Corr, 2022; Aggarwal et al, 2024). Lactobacilli play significant roles in food, industry, and health (humans and veterinary). They are essential in the production of fermented food, enhancing food texture and preservation. Industrially, they are used to produce lactic acid through carbohydrate fermentation, serving as a precursor for bioplastics. In the health sector, many strains of lactobacilli are marketed as probiotics, providing benefits in addition to basic nutrition. Furthermore, emerging research is focused on exploring their role as therapeutics and as delivery vehicles for vaccines (Sun et al, 2015; Zheng et al, 2015; Stefanovic et al, 2017). Lactobacilli in various food and animal sources and associated benefits have been summarized in Table 1.

Role of *Lactobacillus* in Enhancing Gut Health

Lactobacilli occur indigenously in the gut microbiota of animals and humans (Al-Yami et al, 2022; Averina et al, 2021), where they exert beneficial effects on the host's health (Ilinskaya et al, 2017). They are acid tolerant and have the ability to hinder the growth of diverse pathogenic bacteria and fungi, primarily through lactic acid production. Probiotic lactobacilli adopt various mechanisms to colonize intestinal epithelium, thereby sustaining the integrity of the gut barrier, enhancing mucosal defense, and regulating host immunity. The recovery of lactobacilli from excreta or feces reflects their existence and distribution in the GIT (Rastogi and Singh, 2022; Ludfiani et al, 2021; Rosique et al, 2019). Numerous *Lactobacillus* spp. are widely utilized to support and enhance the activity of the GIT and help with the nutrient absorption in livestock and humans (Zommiti et al, 2020).

Role of *Lactobacillus* in Food Production

Lactobacillus strains, due to their fermentative character and related nutritional and health-promoting capabilities, are broadly utilized in the manufacturing of foods (Yao et al, 2025; Adesulu-Dahunsi et al, 2022). Many studies have emphasized their importance in guaranteeing the safety and

quality of fermented food (Chaves-López et al, 2020; Goel et al, 2020). Lactobacilli are often used to ferment food, and they are used as starter cultures to produce fermented vegetables, dairy products, and meat (Aryana and Olson, 2017). In addition to the technological aspect, these bacteria are highly beneficial in the preservation of food by prolonging their shelf life by synthesizing organic acids and antimicrobial metabolites. In the presence of such compounds, pathogens and spoilage causing organisms can't survive, and hence, they maintain the stability and safety of fermented foods (Adesulu-Dahunsi et al, 2022).

Antibiotic Resistance in *Lactobacillus* species

Antibiotic resistance (AR) is the capability of bacteria and other microbes to tolerate the effects of antibiotics that could reduce their growth or eliminate them. Several mechanisms account for the development of antibiotic resistance, including the level of resistance exhibited by a bacterial strain and its ability to persist through various resistance mechanisms (Muteeb et al, 2023). The World Health Organization has identified antibiotic resistance as a major worldwide threat to both food safety and public health (Wang et al, 2021). AR in probiotic lactobacilli is regarded as an important feature for their potential

Table 1: Lactobacilli isolated from diverse sources and their benefits.

Source	Lactobacillus strains.	Positive Effects	Reference
GIT of Animals			
Turkeys	<i>L. ruteri</i> , <i>L. johnsonii</i> , <i>L. frumenti</i>	Expressed probiotic properties, antimicrobial potential	(Altarugio et al, 2018)
Calves	<i>L. fermentum</i> , <i>L. farciminis</i>	Resistance to gastrointestinal conditions, antibiotic susceptibility, antimicrobial activity	(Sandes et al, 2017)
Chicken	<i>L. farciminis</i> , <i>L. salivarius</i> , <i>L. fermentum</i> , <i>L. ingluviei</i> , <i>L. plantarum</i> , <i>L. acidophilus</i>	strong antibacterial activity, Robust Probiotic potential	(Thuy and Trai, 2024; Sirisopapong et al, 2023; Sorescu et al, 2021; Khan et al, 2019)
Food Sources			
Yogurt	<i>L. acidophilus</i> , <i>L. delbrueckii</i> subsp. <i>bulgaricus</i> , <i>L. casei</i> , <i>L. paracasei</i> ,	Enhancing gut health, modulating the immune health, and helping with conditions like diabetes, cardiovascular diseases, and osteoporosis	(Ibrahim et al, 2023; Refaat et al, 2025)
Whey	<i>L. plantarum</i> and <i>L. fermentum</i>	Cholesterol-lowering activity, antibacterial activity	(Rzepkowska et al, 2017; Zielińska and Kolożyn-Krajewska, 2018)
Cheese	<i>L. plantarum</i> , <i>L. brevis</i> , <i>L. delbrueckii</i> subsp. <i>lactis</i> , <i>L. rhamnosus</i>	Reducing aflatoxin M1 in milk, Enhance gastrointestinal health, boost immunity, lower cholesterol, reducing lactose intolerance, and improving oral health by diminishing dental caries and yeast infections	(Hamam and Ahmed, 2019; Erfanpoor et al, 2024)
Dairy Beverages	<i>L. paracasei</i> , <i>L. acidophilus</i> , <i>L. plantarum</i> , <i>L. rhamnosus</i>	Promote gut health, Immunity enhancement, Antioxidant activity	(Turkmen et al, 2019; Liu et al, 2024)
Kefir	<i>L. kefirifaciens</i> , <i>L. delbrueckii</i> subsp. <i>lactis</i> , <i>L. delbrueckii</i> ssp. <i>bulgaricus</i>	Lowering cholesterol levels, protecting against diabetes, possessing antimicrobial and anticarcinogenic properties	(Georgalaki et al, 2021; Egea et al, 2022; Refaat et al, 2025)
Sauerkraut	<i>L. plantarum</i> , <i>L. brevis</i> , <i>L. paracasei</i> ,	Antioxidant, bacteriocin production antimicrobial, strong resistance to gastrointestinal conditions	(Chaudhary and Saharan, 2019; Yang et al, 2020; Fadare et al, 2023)
Kimchi	<i>L. fermentum</i> , <i>L. curvatus</i> , <i>L. reuteri</i> , <i>L. rhamnosus</i> , <i>L. paracasei</i> , <i>L. sakei</i> , <i>L. salivarius</i> ,	Acid-bile resistance, lowering cholesterol, modulating inflammatory process, antibacterial activity	(Lee et al, 2022; Seo et al, 2021)
Fruit vinegars	<i>L. paracasei</i> , <i>L. plantarum</i> , <i>L. brevis</i> ,	Antimicrobial activity, reducing oxidative stress, blood-glucose lowering activity, reducing obesity, anti-tumor activity, reducing hypertension, reducing the possibility of cardiovascular diseases	(Sengun et al, 2022)
Fermented meat products	<i>L. plantarum</i> , <i>L. brevis</i>	Resistance to gastrointestinal conditions, antimicrobial activity	(Rzepkowska et al, 2017, Zielińska and Kolożyn-Krajewska, 2018; Sivamaruthi et al, 2022)

application alongside antibiotic therapy. However, the consumption of bacteria carrying acquired resistance raises concerns due to the possibility of spreading the resistance determinants within the gut microbiota, more broadly, into the environment (Anisimova and Yarullina, 2019; Anisimova et al, 2022).

Mechanisms of Antibiotic Resistance in Lactobacilli

To become resistant to antibiotics, *Lactobacillus* employs diverse and sophisticated mechanisms. By changing their receptors without changing the antibiotic component (passive effect) or by modifying the antibiotic agent with enzymes (active effect), they can avoid the effects of antibiotics (Álvarez-Cisneros and Ponce-Alquicira, 2018). Transferable antibiotic resistance genes are present in the *Lactobacillus* group, which acts as a carrier of these genes and passes them on to non-resistant individuals. These populations are forced to create defense mechanisms against antibiotics when they are exposed to them (Sharma et al, 2014; Ojha et al, 2021).

The major mechanisms by which lactobacilli develop resistance to antibiotics are:

- 1) Enzymatic alteration of antibiotics, which causes structural modification in the antibiotic compound and prevents its interaction with the target.
- 2) Enzymatic degradation of antibiotics, occurring at either intracellular or extracellular level, thus neutralizing the antibiotic action.
- 3) Activation of efflux pumps, which pump antibiotics actively out of the cell, thereby reducing the amount of drug inside the cell.
- 4) Modification in permeability of the cell wall, resulting in decreased intracellular concentration of antibiotic. Among these mechanisms, multidrug resistant efflux pumps are considered the predominant mechanism causing resistance in lactobacilli (Fraqueza, 2015; Von Wintersdorf et al, 2016).

Intrinsic vs. Acquired Resistance

Lactobacilli can exhibit either intrinsic (primary) resistance or acquired (secondary) resistance to antibiotics (Zheng et al, 2024). Intrinsic resistance is a genetically encoded trait inherent to a bacterial species. It reflects the innate capability of bacteria to resist certain antibiotics due to innate structural

or functional features, such as reduced cell membrane permeability, active efflux pumps, or lack of specific drug targets (Poulton and Rock, 2022). Generally, it is not considered a safety concern. The majority of *Lactobacillus* strains are naturally resistant to the aminoglycoside group of antibiotics (kanamycin, neomycin, streptomycin, and gentamicin), trimethoprim, bacitracin, ciprofloxacin, cefoxitin, nitrofurantoin, vancomycin, and metronidazole (Abriouel et al, 2015; Álvarez-Cisneros and Ponce-Alquicira, 2018; Duche et al, 2023). In contrast, they show sensitivity to beta-lactams, tetracycline, linezolid, chloramphenicol, and erythromycin. However, many studies have reported resistance in *Lactobacillus* strains against these antibiotics, which is most likely acquired (Abriouel et al, 2015; Anisimova and Yarullina, 2019).

Acquired resistance is defined by the ability of bacteria to resist the antibiotics to which they were sensitive previously. This occurs typically through two main processes: horizontal gene transfer (HGT) and genetic mutations within chromosomal DNA (Kumawat et al, 2023). Among the factors contributing to the resistance spread, mobile genetic elements facilitating the horizontal transfer of resistance genes pose a major risk (Dušková et al, 2021, Zavišić et al, 2023). Analytical assessment of antibiotic resistance is generally carried out by employing phenotypic methods such as disk diffusion, E-test, and dilution assays (Colautti et al, 2022) as described in Table 2. However, these techniques are incapable of differentiating between intrinsic and acquired resistance, making them helpful only as preliminary tests, and must be complemented with molecular (genotypic) methods for precise characterization of antibiotic resistance. The focus of recent research is to study antibiotic sensitivity profiles and resistance genes (ARGs) in lactobacilli. To date, many antibiotic resistance genes, both intrinsic and acquired, in *Lactobacillus* spp. have been reported (Anisimova and Yarullina, 2019; Anisimova et al, 2022). Primers utilized, in various studies, for the detection of ARGs in *Lactobacillus* strains have been described in Table 3.

Horizontal Transfer of ARGs

Three mechanisms can cause horizontal transfer of resistance genes: *transformation*, which involves obtaining foreign genetic material from the extracellular environment (Duche et al, 2023); *transduction*, which involves

Table 2: Phenotypic characterization of antibiotic resistance in lactobacilli obtained from various sources.

Antibiotic	Mode of Activity	Source	Phenotypic Method for AR Assessment	Reference
Bacitracin, cephalosporins, methicillin, vancomycin, ampicillin, polymyxin, penicillin	Hinder synthesis of cell wall	Traditional fermented foods, Yogurt, Fermented beverage, nutritional supplements and probiotic formulations	Minimum Inhibitory Concentration (MIC) Assay, Disk diffusion technique	(Poornachandra Rao et al, 2015; Campedelli et al, 2019; Sornsenee et al, 2021; Anisimova et al, 2022; Duche et al, 2023)
Streptomycin, gentamycin, chloramphenicol, tetracycline, neomycin, erythromycin, clindamycin, aminoglycosides, chlortetracycline, kanamycin	Suppress biosynthesis of proteins	Milk and dairy items, yogurt, starter cultures, poultry gut and feces	MIC, E-test, disk diffusion	(Zhou et al, 2005; Huys et al, 2008; Poornachandra Rao et al, 2015; Saleem et al, 2018; Campedelli et al, 2019; Wang et al, 2019; Dec et al, 2020; Shafiei et al, 2021)
Norfloxacin, ciprofloxacin, enrofloxacin nalidixic acid	Block replication of DNA	Fruits, dairy items, fermented foods, feces of piglets, starter cultures	MIC, E-test, disk diffusion	(Zhou et al, 2005; Hummel et al, 2007; Karapetkov et al, 2011; Poornachandra Rao et al, 2015; Zou et al, 2017; Campedelli et al, 2019; Duche et al, 2023)
Sulfonamides/trimethoprim	Inhibit folate synthesis	Dairy items, fruits	MIC	(Muñoz et al, 2014; Karapetkov et al, 2011)

Table 3: Primers employed in various studies to detect ARGs.

Antibiotic Group	Target Gene	Primer Sequence (5'→3')	Amplicon Size (bp)	Reference
Aminoglycosides	<i>aac(6')-Ie-aph(2'')-Ia</i>	CAGAGCCTTGGGAAGATGAAG	348	(Dang et al, 2023; Duche et al, 2023, Vakulenko and Mobashery, 2003)
	<i>ant(6)-Ia</i>	CCTCGTGTAAATTCATGTTCTGGC	563	Duche et al, 2023, Kobayashi et al, 2001)
		CGGGAGAATGGGAGACTTTG		
		CTGTGGCTCCACAATCTGAT		
	<i>aad6</i>	CTTTAGCAGAACAGGA TG	844	(Jaimee and Halami, 2016; Donabedian et al, 2003)
		CCGGCCTCTCTTCTAT ATC		
	<i>aph(3')IIIa</i>	GCCGATGTGGATTGCGAAAA	292	(Wang et al, 2018; Rojo-Bezares et al, 2006)
		GCTTGATCCCCAGTAAGTCA		
	<i>aadE</i>	ATGGAATTATTTCCACCTGA	1060	Obioha et al, 2023, Dec et al, 2018; Van Duijkeren et al, 2014)
		TCAAAACCCCTATTAAGCC		
Macrolides & Lincosamides	<i>ere(A)</i>	AACACCCTGAACCCAAGGGACG	420	(Wang et al, 2018; Sutcliffe et al, 1996)
		CTTCACATCCGGATTTCGCTCGA		
	<i>erm(A)</i>	CCCGAAAAATACGAAAAATTTTCAT	590	(Dec et al, 2018; Malhotra-Kumar et al, 2005)
		CCCTGTTTACCCATTATAAACG		
	<i>erm(B)</i>	TGGTATTCCAAATGCGTAATG	745	(Duche et al, 2023; Dec et al, 2018)
Tetracyclines		CTGTGGTATGGCGGGTAAGT		
	<i>Inu(A)</i>	GGTGGCTGGGGGTAGATGTATTA	323	(Duche et al, 2023; Kastner et al, 2006)
		ACTGGGCTTCTTTGAAATACATGGT		
		ATTTTTCGATC		
	<i>tet(O)</i>	AACTTAGGCATTCTGGCTCAC	515	(Duche et al, 2023; Dec et al, 2018)
		TCCCACTGTTCCATATCGTCA		
	<i>tet(S)</i>	TGGAACGCCAGAGAGGTATT	660	(Shao et al, 2015; Ouoba et al, 2008)
		ACATAGACAAGCCGTTGACC		
	<i>tet(M)</i>	GTAAATAGTGTCTTCTGGAG	576	(Dang et al, 2023; Saleem et al, 2018; Nawaz et al, 2011)
		CTAAGATATGGCTCTAACAA		
Fluoroquinolones	<i>tet(K)</i>	TAGGTGAAGGGTTAGGTCC	697	(Duche et al, 2023; Shao et al, 2015; Aarestrup et al, 2000)
		GCAAATCATTCCAGAAGCA		
	<i>tet(L)</i>	TGGTGGAATGATAGCCATT	229	(Dec et al, 2018; Malhotra-Kumar et al, 2005)
		CAGGAATGACAGCACGCTAA		
	<i>tet(W)</i>	GAGAGCCTGCTATATGCCAGC	168	(Dang et al, 2023; Duche et al, 2023; Kastner et al, 2006)
		GGGCGTATCCACAATGTTAAC		
	<i>gyrA</i>	CAMCGKCGKATTCTTTACGGAATG	286	(Duche et al, 2023; Shao et al, 2015; Hummel et al, 2007)
		TTRTTGATATCRGBAGCATTTTC		
	<i>parC</i>	TATTCYAAATAYATCATTTCARGA	286	
		GCYTCNGTATAACGCATMGCCG		
Beta lactams	<i>blaTEM</i>	GGTCGCCGCATACACTATTCTC	372	(Rokon-Uz-Zaman et al, 2023; Le et al, 2015)
		TTTATCCGCCTCCATCCAGTC		
	<i>blaCTX-M-1</i>	GAATTAGAGCGGCAGTCGGG	588	
Glycopeptides		CACAACCCAGGAAGCAGGC		
	<i>blaCTX-M-2</i>	GATGGCGACGCTACCCC	107	
		CAAGCCGACCTCCCGAAC		
Glycopeptides	<i>VanX</i>	TCGCGGTAGTCCCACCATTCGTT	454	(Dang et al, 2023; Shao et al, 2015; Chang et al, 2009)
		AAATCATCGTTGACCTGCGTTAT		

incorporating fragments of the bacterial DNA into the bacteriophage genome during replication, which then infects another bacterial cell, resulting in the transfer of genetic material (Lerner et al, 2017); or *conjugation*, which involves DNA transfer induced by cell-to-cell contact (Duche et al, 2023; Morawska et al, 2023). The difficulty of precisely detecting and tracking these DNA exchanges is a significant obstacle to HGT. Plasmid-mediated transfer is the most common HGT mechanism, allowing resistance genes to be exchanged between several taxonomic groups (Kerek et al, 2025).

Antibiotic Resistance in Animal-Derived *Lactobacillus* spp. Aminoglycoside Resistance

Because lactobacilli lack cytochrome dependent electron transport (Dušková et al, 2021; Gueimonde et al, 2013), which promotes drug uptake and reduced membrane permeability (Duche et al, 2023), they are inherently resistant to aminoglycoside antibiotics. *Lactobacillus* species isolated from agricultural settings frequently include aminoglycoside resistance genes, which aid in the

proliferation of harmful bacteria in the gastrointestinal microbiota through horizontal gene transfer (HGT) and enhanced tolerance through structural alterations (Jaimee and Halami, 2016). Since gentamicin is a key medication of choice for treating infections in both humans and animals, aminoglycosides, in particular kanamycin and gentamicin resistance in lactobacilli, should be assessed carefully (Das et al, 2020).

Phenotypic Resistance

High-level resistance to aminoglycosides has been frequently reported in animal-derived *Lactobacillus* isolates. *Lactobacillus* strains obtained from domestic geese displayed resistance to neomycin (27%), and 50% strains were resistant to fluoroquinolones like flumequine and enrofloxacin, with over 44% resistant to protein synthesis inhibitors including aminoglycosides (Dec et al, 2015). Dec et al. (2018), in a study, revealed that 10% of lactobacilli from turkeys were resistant to gentamicin, while 31% showed streptomycin resistance. In poultry-origin lactobacilli, particularly from the broiler gut,

resistance to gentamicin and streptomycin was noted, especially in commercial poultry isolates (Saleem et al, 2018). Rajoka et al. (2018) also documented 100% resistance to streptomycin and gentamicin in the tested *Lactobacillus* strains from poultry intestines.

Genotypic Resistance

Genes resistant to aminoglycosides have frequently been documented. In a study by Jaimee and Halami, (2016), *Lactobacillus* strains from meat and farm animal sources were shown to have *aac(6')Ie-aph(2'')Ia* and *aph(3'')IIIa* genes. Similarly, *ant(6)-Ia*, and *aad6* were identified in chicken-derived *Lactobacillus* strains (Dec et al, 2017). In addition, Xu et al. (2024) reported the existence of elfamycin resistance genes in pig-derived *Lactobacillus* species. Some of these resistant genes are associated with plasmid and could serve as a reservoir of antibiotic resistance dissemination among other gut pathogens, with the potential to transfer to humans via the food chain. So, antibiotic resistance patterns in these bacteria and relative transferability to other bacteria should be assessed properly before their use as probiotics.

Macrolide and Lincosamide Resistance

Although the majority of lactobacilli are normally sensitive, some strains exhibit resistance to macrolides and lincosamide, suggesting that this resistance is acquired instead of intrinsic (Reefat et al, 2025).

Phenotypic Resistance

Resistance to erythromycin and lincomycin has been widely observed and reported in lactobacilli associated with the GIT. For instance, *Lactobacillus* strains recovered from the gut of chickens displayed erythromycin resistance rates as high as 87% in commercial birds (Saleem et al, 2018). Moreover, Dec et al. (2015) found 15% of goose-derived lactobacilli resistant to lincomycin, while, Dec et al. (2018) observed that 45% of the lactobacilli obtained from feces of turkeys were resistant to erythromycin. Sirisopapong et al. (2023) observed that all poultry-derived *Lactobacillus* strains were resistant to erythromycin.

Genotypic Resistance

Erythromycin resistance correlates with the genes *erm(B)*, *erm(C)*, *erm(T)* and *erm(A)*. The *erm(B)* gene is the most common and frequently reported gene in the genus *Lactobacillus*, and it encodes ribosomal RNA methylase that binds to the 23 S subunit (Gad et al. 2014; Sharma et al. 2016; Campedelli et al 2019). Preethi et al. (2017) confirmed the existence of *erm(B)* in poultry isolates in addition to *msr(A/B)* and *msr(C)*. Dec et al. (2017) found *erm(B)* in 39% of tested isolates. They also observed the lincosamide resistance gene *lnu(A)*. These genes are commonly associated with mobile genetic components such as the *Tn916* transposon family. Their mobility raises concerns about horizontal spread to other gut microorganisms and consequent dispersion into the food chain. Moravkova et al. (2022) also observed *erm(B)* genes in *Lactobacillus* strains recovered from pigs.

Tetracycline Resistance

Tetracyclines are extensively used antibiotics in animal rearing due to their broad-spectrum activity, low cost of

production and absence of any major side effects (Jamal et al, 2017; Ma et al, 2021). Tetracycline resistance is among the best studied characteristics of lactobacilli; 11 resistance genes have been discovered, such as *tet(O)*, *tet(W)*, *tet(Q)*, *tet(M)*, *tet(S)*, *tet(36)*, *tet(K)*, *tet(L)*, *tet(O/W/32/O/W/O)* and *tetZ* (Anisimova and Yarullina, 2018; Anisimova and Yarullina, 2019). Most of these genes, especially *tet(K)* and *tet(L)*, are coded on plasmids, but some are chromosomally-coded and plasmid-coded as in the case of *tet(M)*, *tet(O)* and *tet(Q)*. The resistance mechanism is either via the ribosome protection or efflux pumps (Das et al, 2020).

Phenotypic Resistance

Resistance to tetracycline group of antibiotics is highly prevalent in animal-derived *Lactobacillus* isolates. Dec et al. (2017) observed tetracycline resistance in 74% of *Lactobacillus* strains, while Preethi et al. (2017) witnessed elevated levels of resistance in isolates from conventional poultry. Saleem et al. (2018) also reported moderate resistance in poultry-derived lactobacilli (41% in commercial vs. 32% in indigenous isolates). Dec et al. (2018) found that 68% of turkey-origin lactobacilli exhibited resistance. Likewise, resistance among pig fecal *Lactobacillus* isolates has also been reported (Xu et al, 2024). Lactobacilli are generally reported to exhibit sensitivity to tetracyclines, however, reported resistance against these antibiotics necessitates thorough investigation and assessment.

Genotypic Resistance

Lactobacilli isolated from animals are often reported to harbor tetracycline resistance genes. Dec et al. (2017) tested *Lactobacillus* species obtained from chicken and found that 45%, 26%, and 24% of isolates carried the genes *tet(W)*, *tet(M)*, and *tet(L)*, respectively. While *tet(K)* was also detected by Preethi et al. (2017), and all of these were linked with mobile elements such as *Tn916/Tn917*. Dec et al. (2018) found *tet(W)* (37%), *tet(L)* (40%), and *tet(M)* (29%) genes in lactobacilli obtained from turkeys. Saleem et al. (2018) detected and sequenced *tet(M)* genes from poultry-derived lactobacilli and revealed >99% identity with *tet(M)* from *E. coli*, suggesting the possibility of interspecies transfer and dissemination via the food chain. Dec et al. (2020) observed the prevalence of tetracycline-resistant genes in *Lactobacillus* species isolated from pigeons; they found that 79% of the isolates carried *tet(L)*, *tet(M)*, and *tet(W)* genes.

Fluoroquinolone Resistance

A common subclass of quinolone antibiotics, fluoroquinolones, like ciprofloxacin, have a fluorine atom associated with the core ring structure, which increases their efficacy against bacterial infections (Reefat et al, 2025). By preventing type II topoisomerases, particularly topoisomerase IV and DNA gyrase, from introducing supercoiling into DNA, quinolones prevent bacteria from replicating their DNA (Collins et al, 2024). This inhibition causes DNA to be accumulated with single and double-strand breaks, which blocks DNA unwinding and replication, thereby hindering bacterial surviving and multiplication (Bush et al, 2020; Lungu et al, 2022).

Phenotypic Resistance

Resistance to fluoroquinolones in animals-originated lactobacilli has often been reported. Dec et al. (2015) observed high resistance (60%) in *Lactobacillus* spp. recovered from geese. Dec et al. (2017) found 48% of the chicken-derived lactobacilli resistant to enrofloxacin. Saleem et al. (2018), also witnessed extremely high levels of resistance (>80%) against ofloxacin, ciprofloxacin, and levofloxacin in *Lactobacillus* isolates obtained from indigenous and commercial poultry. However, Zou et al. (2017) observed elevated levels of enrofloxacin resistance in lactobacilli recovered from post-weaned piglets.

Genotypic Resistance

Fluoroquinolone resistance has been found to occur because of the mutations in the quinolone resistance determining regions (QRDR) of the *parC* or *gyrA* gene (Das et al, 2020). Although quinolone-resistant genes are mostly prevalent in food-originated *Lactobacillus* strains (Guo et al, 2017), some studies also report their existence in animal isolates. Dec et al. (2020) observed and sequenced the *gyrA* gene in lactobacilli that expressed high phenotypic resistance to enrofloxacin.

Beta-lactam Resistance

Because of their structural resemblance to the substrate D-alanyl-alanine, β -lactam antibiotics like ampicillin target PBPs by blocking peptidoglycan cross-linking (Kim et al, 2023). While most lactobacilli are naturally vulnerable to these antibiotics (Saini and Tomar, 2017; Anisimova and Yarullina, 2019), various strains of *Lactobacillus* have been shown to be resistant in several investigations.

Phenotypic Resistance

Resistance to β -lactam antibiotics like ampicillin and amoxicillin in lactobacilli obtained from animals has often been reported. Dec et al. (2018) found 47% turkey-derived lactobacilli resistant to ampicillin. Rajoka et al. (2018) reported 100% resistance to penicillin. Saleem et al. (2018) noted higher ampicillin resistance in indigenous poultry (49%) compared to commercial poultry (43%). Tsega et al. (2023) found 90% chicken-derived lactobacilli resistant to ampicillin. These findings are of great concern for both animals and public health, as beta-lactam antibiotics serve as an important treatment option in animals and humans.

Genotypic Resistance

Resistance genes for β -lactam antibiotics have not been reported commonly in animal-derived lactobacilli. Aquilanti et al. (2007) observed *blaZ* gene in animal-derived lactobacilli. Aristimuño Ficooseco et al. (2018) also detected *bla* genes in cattle-derived lactobacilli. Moreover, *blaCTX-M-2*, *blaCTX-M-1*, and *blaTEM* were identified in some poultry probiotic products-derived *Lactobacillus* strains. These genes were shown to have potential for horizontal transfer to other gut bacteria in co-culture experiment (Rokon-Uz-Zaman et al, 2023).

Antibiotic Resistance in Food-derived *Lactobacillus* spp.

Aminoglycoside Resistance

Phenotypic Resistance

Lactobacilli from fermented food items, particularly dairy and meat, have shown significant resistance to

aminoglycosides. Wang et al. (2018) found high resistance to streptomycin and kanamycin in *Lactobacillus* spp. from Chinese cured beef. Erginkaya et al. (2018) also observed gentamicin resistance in *Lactobacillus* spp. isolated from traditional Turkish dairy products. In a study of yogurt and cheese products, Wang et al. (2019) observed high resistance against neomycin, gentamicin, and streptomycin in *Lactobacillus* isolates from cheese and yogurt products.

Genotypic Resistance

Genes conferring resistance to the aminoglycoside group of antibiotics, such as *aph(3')IIIa*, *aad6*, and *aac(6')Ie-aph(2'')Ia*, in food-originated *Lactobacillus* strains have been reported in many studies (Shao et al, 2015; Jaimee and Halami, 2016; Ledina et al, 2018) and are often linked with MGEs, suggesting horizontal gene transfer potential. Wang et al. (2019) also observed the genes *aph* and *aadA2* in lactobacilli recovered from yogurt and cheese. Dušková et al. (2021) found the streptomycin resistance gene *aadE*. Moghimi et al. (2023) found the *aacA-D* gene in majority of the *L. bulgaricus* strains recovered from yogurt. These findings highlight the potential risk of horizontal gene transferability, necessitating the removal of such strains from the food industry.

Beta-lactam Resistance

Phenotypic Resistance

Lactobacilli are naturally sensitive to beta-lactam antibiotics; however, resistance in food-derived lactobacilli has been reported in several studies. Sharma et al. (2016) reported resistance against penicillin, ampicillin, amoxycylav, sulbactam, methicillin, oxacillin, cefotaxime, and cloxacillin. Dušková et al. (2021) also observed ampicillin resistance in food-originated lactobacilli. Duche et al. (2023) also observed strong resistance against beta-lactam antibiotics in lactobacilli recovered from fermented foods.

Genotypic Resistance

Anisimova and Yarullina, (2019) reported widespread existence of the *blaTEM* gene in *Lactobacillus* strains obtained from fermented plant source; however, they also detected *blaSHV* and *blaOXA-1* genes. Zarzecka et al. (2022) reported the presence of the *blaOXA* gene in *Lactobacillus* spp. obtained from food sources. Anisimova et al. (2022) also observed the widespread existence of the *blaTEM* gene in *Lactobacillus* spp. obtained from probiotic preparations. These genes are strongly linked with mobile genetic elements, holding the potential for horizontal transfer.

Fluoroquinolones Resistance

Phenotypic Resistance

Widespread resistance to ciprofloxacin and norfloxacin has been witnessed in food-originated lactobacilli. Anisimova et al. (2022) observed quinolone resistance in all the *Lactobacillus* strains obtained from nutritional supplements and probiotic products. Erginkaya et al. (2018) observed moderate to high resistance levels in *Lactobacillus* spp. derived from dairy foods. Seyirt et al. (2024) also found high resistance against ciprofloxacin, enrofloxacin, and norfloxacin in *Lactobacillus* isolates from dairy probiotic products.

Genotypic Resistance

Guo et al. (2017) detected *gyr(A)* in 30% of fermented milk-derived *Lactobacillus* isolates. Rokon-Uz-Zaman et al. (2023) observed plasmid-encoded quinolone resistance gene *qnrS* in isolates from poultry probiotic products. However, widespread existence of *parC* gene in probiotic products and food-origin *Lactobacillus* strains has also been reported (Anisimova and Yarullina, 2019; Anisimova et al, 2022; Duche et al, 2023).

Macrolide and Lincosamide Resistance

Phenotypic Resistance

Lactobacilli present in fermented dairy and meat products commonly exhibit erythromycin and lincomycin resistance. Erginkaya et al. (2018) documented erythromycin resistance in 11% of *Lactobacillus* spp. isolated from Turkish dairy items. Wang et al. (2018) documented high resistance against erythromycin in beef derived lactobacilli. Seyirt et al. (2024) noticed that 28% of lactobacilli obtained from dairy products demonstrated resistance to erythromycin. The resistance to erythromycin in lactobacilli seems to have declined over time, and recent research reports that resistance occurs in particular locations (Vahabzadeh and Özpınar, 2018).

Genotypic Resistance

Macrolide resistance genes are very common across food ecosystems. Wang et al. (2018) identified the *ere(A)* gene in lactobacilli of beef. Functional plasmids carrying *erm(B)* genes were detected in cheese-derived lactobacilli (Flórez et al, 2021). *Inu(A)*, *msr(C)* and *erm(B)* genes were found in *Lactobacillus* strains having the potential to be used as probiotic silage inoculants and feed supplements by (Stefańska et al, 2021).

Tetracycline Resistance

Phenotypic Resistance

Tetracycline resistance has widespread existence in lactobacilli of food origin. Dec et al. (2018) found tetracycline resistance in 68% of turkey isolates. Varying levels of tetracycline resistance have also been observed in isolates from dairy and cured meat (Erginkaya et al, 2018; Wang et al, 2018). Stefańska et al. (2021) reported high resistance against tetracycline in *Lactobacillus* strains having the potential to be used as feed supplements. Amelia et al. (2024) also observed strong tetracycline resistance in *Lactobacillus fermentum* strains recovered from *dadih Lintau*.

Genotypic Resistance

Among genes conferring resistance to tetracycline, the *tet(M)* gene has been documented as the most prevalent gene in lactobacilli of food origin (Guo et al, 2017; Ledina et al, 2018; Wang et al, 2018; Zarzecka et al, 2022). Rozman et al. (2020) detected the *tet(W)* gene in lactobacilli derived from starter cultures. Rodríguez-Sánchez et al. (2021) observed *tet(O)*, *tet(M)*, *tet(L)*, and *tet(S)* genes in fermented food-associated *Lactobacillus* strains. These genes often accompany the mobile genetic elements, increasing the risk of transferability.

Vancomycin Resistance

Vancomycin resistance in lactobacilli is because of the D-alanyl D-alanine ligase-related enzymes (Campedelli et al,

2019; Selim et al, 2022). The drug interacts with the D-alanine terminus of peptidoglycan precursors, thereby inhibiting their polymerization and cell wall synthesis in susceptible bacteria. However, in the resistant bacteria like *Lactobacillus*, D-alanine is substituted with D-lactate or D-serine, which inhibits vancomycin binding and supports the formation of cell walls (Das et al, 2020).

Phenotypic Resistance

Vancomycin resistance, apparently intrinsic, has been reported widely in food-derived lactobacilli. Guo et al. (2017) and Rodríguez-Sánchez et al. (2021) reported 100% vancomycin resistance in *Lactobacillus* spp. recovered from fermented dairy foods. Erginkaya et al. (2018) found 58% of dairy product-derived *Lactobacillus* spp. resistant to vancomycin. Anisimova et al. (2022) also observed high resistance against vancomycin in *Lactobacillus* strains obtained from probiotic products and nutritional supplements.

Genotypic Resistance

Vancomycin resistance genes *van(X)* and *van(E)* have been detected in several isolates from fermented food (Guo et al, 2017; Anisimova et al, 2022; Dang et al, 2023). However, *van(A)*, and *van(B)* genes (often linked with MGEs) have also been detected in lactobacilli recovered from fermented foods (Rodríguez-Sánchez et al, 2021).

Conclusion and Future Outlook

Today, there is a great significance of LAB, particularly *Lactobacillus* spp, and the health advantages that go along with them because of their increasing usage as probiotics in food industry and livestock rearing. It is impossible to ignore the issue of AR in lactobacilli, though. Acquired resistance offers a more complicated situation, even if lactobacilli's intrinsic resistance may increase their survival in hostile antimicrobial settings. Acquired resistance can lead to the spread of AR and related health issues, as well as provide the risk of transferring resistance genes to other pathogenic and beneficial gut bacteria. As lactobacilli are introduced to an already wide range of food products and nutritional supplements, it is even more significantly increased as probiotic markets expand.

The potential threat of horizontal transmission within the gut microbiota and along the food chain is emphasized by the common occurrence of resistance genes to clinically relevant antibiotics in isolates obtained of food and animals, e.g, tetracyclines, macrolides, aminoglycosides, b-lactams as well as fluoroquinolones. This underscores the importance of implementing stringent legislations on the application of antibiotics in animal and food production systems, and the fact that all probiotic candidate strains should pass through stringent AR screening. The strains containing resistance genes, particularly those associated with mobile genetic elements, should be further examined and tested to determine their susceptibility to antibiotics, according to the instructions issued by EFSA. The identification and prediction of ARGs has been made convenient by recent advances in metagenomics, bioinformatics, and artificial intelligence. The adoption of these technologies will help companies to improve their formulation, reducing resistance concerns and understanding better the impact of implementing novel probiotics, leading to safer products to the consumer.

In short, a well-coordinated approach is required. This includes stringent safety standards by manufacturers, increased regulatory surveillance and inventive technological applications. Researchers, regulatory bodies, stakeholders, and medical professionals need to collaborate efficiently to ensure exchange of data, standardized safety requirements and on-going risk evaluation. Together, such synchronized activities will maintain the benefits of using *Lactobacillus* as probiotics in livestock and food production systems and reduce the associated risks, ensuring that the practice can continue to be effective and safe in promoting consumer health.

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REFERENCES

- Aarestrup FM, Agero Y, Gerner-Smidt, P, Madsen, M. and Jensen, L.B, 2000. Comparison of antimicrobial resistance phenotypes and resistance genes in *Enterococcus faecalis* and *Enterococcus faecium* from humans in the community, broilers, and pigs in Denmark. *Diagnostic Microbiology and Infectious Disease*, 37(2): 127-137.
- Abreu R, Semedo-Lemsaddek T, Cunha E, Tavares L and Oliveira M, 2023. Antimicrobial drug resistance in poultry production: Current Status and innovative strategies for bacterial control. *Microorganisms*, 11(4): 953.
- Abriouel H, Muñoz MDCC, Lerma LL, Montoro BP, Bockelmann W, Pichner R, Kabisch J, Cho GS, Franz CM, Gálvez A and Benomar N, 2015. New insights in antibiotic resistance of *Lactobacillus* species from fermented foods. *Food Research International*, 78, pp.465-481.
- Adeniyi B, Adesuyi A, Ayeni F, Ogunbanwo T and Agidigbi T, 2024. Poultry Gastrointestinal-derived Lactic Acid Bacteria (pGIT-d-LAB) Inhibit Multiple Antibiotics Resistance Bacterial and Fungal Pathogens. *Avicenna Journal of Medical Biotechnology*, 16(2): 111.
- Adesulu-Dahunsi AT, Dahunsi SO and Ajayeoba TA, 2022. Co-occurrence of *Lactobacillus* species during fermentation of african indigenous foods: Impact on food safety and shelf-life extension. *Frontiers in Microbiology*, 13, 684730.
- Aggarwal A, Parmar A, Panigrahi SP, Verma T, Dhyani P, Bajya SL and Singh MS, 2024. Exploring the probiotic and prebiotic dynamics of cheese: An updated review. *Annals of Phytomedicine*, 13(1): 360-369.
- Aggarwal S, Sabharwal V, Kaushik P, Joshi A, Aayushi A and Suri M, 2022. Postbiotics: From emerging concept to application. *Frontiers in Sustainable Food Systems*, 6, p.887642.
- Al-Khalaifa H, Al-Nasser A, Al-Surayee T, Al-Kandari S, Al-Enzi N, Al-Sharrah T, Ragheb G, Al-Qalaf S and Mohammed A, 2019. Effect of dietary probiotics and prebiotics on the performance of broiler chickens. *Poultry Science*, 98(10): 4465-4479.
- Altarugio R, Vellano IHB, Moraes, A.C.I, Milbradt, E.L, Andreatti Filho, R.L, Guimarães-Okamoto, P.T.C, Padovani, C.R. and Okamoto, A.S, 2018. In vitro probiotic selection and characterization of *Lactobacillus* spp. isolated from healthy domesticated Turkeys. *Journal of Applied Poultry Research*, 27(1): 81-91.
- Álvarez-Cisneros YM and Ponce-Alquicira E, 2018. Antibiotic resistance in lactic acid bacteria. *Antimicrobial Resistance-A Global Threat*, pp.53-73.
- Al-Yami AM, Al-Mousa AT, Al-Otaibi SA and Khalifa AY, 2022. *Lactobacillus* species as probiotics: isolation sources and health benefits. *Journal of Pure Applied Microbiology* 16(4): 1761-1770.
- Anisimova E and Yarullina D, 2018. Characterization of erythromycin and tetracycline resistance in *Lactobacillus fermentum* strains. *International Journal of Microbiology*, 2018(1): 3912326.
- Anisimova E, Gorokhova I, Karimullina G and Yarullina D, 2022. Alarming antibiotic resistance of lactobacilli isolated from probiotic preparations and dietary supplements. *Antibiotics*, 11(11): 1557.
- Anisimova EA and Yarullina DR, 2019. Antibiotic resistance of *Lactobacillus* strains. *Current Microbiology*, 76(12): 1407-1416.
- Aquilanti L, Garofalo C, Osimani A, Silvestri G, Vignaroli C and Clementi F, 2007. Isolation and molecular characterization of antibiotic-resistant lactic acid bacteria from poultry and swine meat products. *Journal of Food Protection*, 70(3): 557-565.
- Aristimuño Ficoseco C, Mansilla FI, Maldonado NC, Miranda H, Fátima Nader-Macias ME and Vignolo GM, 2018. Safety and growth optimization of lactic acid bacteria isolated from feedlot cattle for probiotic formula design. *Frontiers in Microbiology*, 9, p.2220.
- Aryana KJ. and Olson DW, 2017. A 100-Year Review: Yogurt and other cultured dairy products. *Journal of Dairy Science*, 100(12): 9987-10013.
- Averina OV, Poluektova EU, Marsova MV and Danilenko VN, 2021. Biomarkers and utility of the antioxidant potential of probiotic lactobacilli and bifidobacteria as representatives of the human gut microbiota. *Biomedicines*, 9(10): 1340.
- Bush NG, Diez-Santos I, Abbott LR and Maxwell A, 2020. Quinolones: mechanism, lethality and their contributions to antibiotic resistance. *Molecules*, 25(23): 5662.
- Campedelli I, Mathur H, Salvetti E, Clarke S, Rea MC, Torriani S, Ross RP, Hill C and O'Toole PW, 2019. Genus-wide assessment of antibiotic resistance in *Lactobacillus* spp. *Applied and Environmental Microbiology*, 85(1): e01738-18.

- Chang LIU, Zhang ZY, Ke DONG, Jian-Ping YUAN. and Xiao-Kui GUO, 2009. Antibiotic resistance of probiotic strains of lactic acid bacteria isolated from marketed foods and drugs. *Biomedical and Environmental Sciences*, 22(5): 401-412.
- Chaudhary A and Saharan BS, 2019. Probiotic Properties of *Lactobacillus plantarum*. *Journal of Pure & Applied Microbiology*, 13(2).
- Chaves-López C, Rossi C, Maggio F, Paparella A and Serio A, 2020. Changes occurring in spontaneous maize fermentation: An overview. *Fermentation*, 6(1): 36.
- Coelho MC, Malcata FX and Silva CC, 2022. Lactic acid bacteria in raw-milk cheeses: From starter cultures to probiotic functions. *Foods*, 11(15): 2276.
- Colautti A, Arnoldi M, Comi G and Iacumin L, 2022. Antibiotic resistance and virulence factors in lactobacilli: something to carefully consider. *Food Microbiology*, 103, p.103934.
- Collins JA, Oviatt AA, Chan PF and Osheroff N, 2024. Target-mediated fluoroquinolone resistance in *Neisseria gonorrhoeae*: actions of ciprofloxacin against gyrase and topoisomerase IV. *ACS Infectious Diseases*, 10(4): 1351-1360.
- Dang HT, Dinh HS, Loc TA and Nguyen LA, 2023. Antibiotic resistance characteristics of potential probiotic *Lactobacillus* strains. *Vietnam Journal of Science and Technology*, 61(6): 975-983.
- Das DJ, Shankar A, Johnson JB and Thomas S, 2020. Critical insights into antibiotic resistance transferability in probiotic *Lactobacillus*. *Nutrition*, 69, p.110567.
- Dec M, Nowaczek A, Stepień-Pyśniak D, Wawrzykowski J. and Urban-Chmiel R, 2018. Identification and antibiotic susceptibility of lactobacilli isolated from turkeys. *BMC Microbiology*, 18(1): 168.
- Dec M, Stepień-Pyśniak D, Nowaczek A, Puchalski A and Urban-Chmiel R, 2020. Phenotypic and genotypic antimicrobial resistance profiles of fecal lactobacilli from domesticated pigeons in Poland. *Anaerobe*, 65, p.102251.
- Dec M, Urban-Chmiel R, Stepień-Pyśniak D and Wernicki A, 2017. Assessment of antibiotic susceptibility in *Lactobacillus* isolates from chickens. *Gut Pathogens*, 9(1): 54.
- Dec M, Wernicki A, Puchalski A and Urban-Chmiel R, 2015. Antibiotic susceptibility of *Lactobacillus* strains isolated from domestic geese. *British Poultry Science*, 56(4): 416-424.
- Dempsey E and Corr SC, 2022. *Lactobacillus* spp. for gastrointestinal health: current and future perspectives. *Frontiers in Immunology*, 13, p.840245.
- Devirgiliis C, Barile S and Perozzi G, 2011. Antibiotic resistance determinants in the interplay between food and gut microbiota. *Genes & Nutrition*, 6(3): 275-284.
- Devirgiliis C, Zinno P and Perozzi G, 2013. Update on antibiotic resistance in foodborne *Lactobacillus* and *Lactococcus* species. *Frontiers in Microbiology*, 4, p.301.
- Donabedian SM, Thal LA, Hershberger E, Perri MB, Chow JW, Bartlett P, Jones R, Joyce K, Rossiter S, Gay K and Johnson J, 2003. Molecular characterization of gentamicin-resistant enterococci in the United States: evidence of spread from animals to humans through food. *Journal of Clinical Microbiology*, 41(3): 1109-1113.
- Duar RM, Lin XB, Zheng J, Martino ME, Grenier T, Pérez-Muñoz ME, Leulier F, Gänzle M and Walter J, 2017. Lifestyles in transition: evolution and natural history of the genus *Lactobacillus*. *FEMS Microbiology Reviews*, 41(Supp_1): S27-S48.
- Duche RT, Singh A, Wandhare AG, Sangwan V, Sihag MK, Nwagu TN, Panwar H and Ezeogu LI, 2023. Antibiotic resistance in potential probiotic lactic acid bacteria of fermented foods and human origin from Nigeria. *BMC Microbiology*, 23(1): 142.
- Dušková M, Morávková M, Mrázek J, Florianová M, Vorlová L and Karpíšková R, 2021. Assessment of antibiotic resistance in starter and non-starter lactobacilli of food origin. *Acta Veterinaria Brno*, 89(4): 401-411.
- Egea MB, Santos DCD, Oliveira Filho JGD, Ores JDC, Takeuchi KP. and Lemes AC, 2022. A review of nondairy kefir products: their characteristics and potential human health benefits. *Critical Reviews in Food Science and Nutrition*, 62(6): 1536-1552.
- Erfanpoor M, Noori N, Gandomi H and Azizian A, 2024. Reduction and binding of aflatoxin M1 in milk by *Lactobacillus plantarum* and *Lactobacillus brevis* isolated from Siahmazgi cheese. *Toxin Reviews*, 43(3): 311-317.
- Erginkaya ZERR, Turhan EU. and Tatlı, D, 2018. Determination of antibiotic resistance of lactic acid bacteria isolated from traditional Turkish fermented dairy products. *Iranian Journal of Veterinary Research*, 19(1): 53.
- Fadare OS, Anyadike CH, Momoh AO and Bello TK, 2023. Antimicrobial properties, safety, and probiotic attributes of lactic acid bacteria isolated from Sauerkraut. *African Journal of Clinical and Experimental Microbiology*, 24(1): 61-72.
- Florez AB, Vazquez L, Rodriguez J and Mayo, B, 2021. Directed recovery and molecular characterization of antibiotic resistance plasmids from cheese bacteria. *International Journal of Molecular Sciences*, 22(15): 7801.
- Floris I, Battistini R, Tramuta C, Garcia-Vozmediano A, Musolino N, Scardino G, Masotti C, Brusa B, Orusa R, Serracca L and Razzuoli E, 2025. Antibiotic resistance in Lactic Acid Bacteria from dairy products in Northern Italy. *Antibiotics*, 14(4): 375.
- Fraqueza MJ, 2015. Antibiotic resistance of lactic acid bacteria isolated from dry-fermented sausages. *International Journal of Food Microbiology*, 212, pp.76-88.
- Gad, GFM, Abdel-Hamid AM and Farag ZSH, 2014. Antibiotic resistance in lactic acid bacteria isolated from some pharmaceutical and dairy products. *Brazilian Journal of Microbiology*, 45, pp.25-33.
- Georgalaki M, Zoumpopoulou G, Anastasiou R, Kazou M. and Tsakalidou E, 2021. *Lactobacillus kefir*anofaciens: From isolation and taxonomy to probiotic properties and applications. *Microorganisms*, 9(10): 2158.
- Goel A, Halami PM and Tamang JP, 2020. Genome analysis of *Lactobacillus plantarum* isolated from some Indian fermented foods for bacteriocin production and probiotic marker genes. *Frontiers in Microbiology*, 11, p.40.
- Gueimonde M, Sánchez BG de los Reyes-Gavilán C and Margolles A, 2013. Antibiotic resistance in probiotic bacteria. *Frontiers in Microbiology*, 4, p.202.
- Hammam AR and Ahmed MS, 2019. Technological aspects, health benefits, and sensory properties of probiotic cheese. *SN Applied Sciences*, 1(9): 1113.
- HM, K. and Kotb, E.E, 2021. Exploring antimicrobial activity of *Lactobacillus* spp.(probiotics) isolated from raw cow's milk against *Staphylococcus aureus* causing bovine mastitis. *Journal of Applied Veterinary Sciences*, 6(3): 60-69.
- Hummel AS, Hertel C, Holzapfel WH and Franz CM, 2007. Antibiotic resistances of starter and probiotic strains of lactic acid bacteria. *Applied and Environmental Microbiology*, 73(3): 730-739.
- Huys G, D'haene K, Danielsen M, Mättö J, Egervärn M and Vandamme P, 2008. Phenotypic and molecular assessment of antimicrobial resistance in *Lactobacillus paracasei* strains of food origin. *Journal of Food Protection*, 71, pp.339-344.
- Ibrahim SA, Yeboah PJ, Ayivi RD, Eddin AS, Wijemanna ND, Paidari S and Bakhshayesh RV, 2023. A review and comparative perspective on health benefits of probiotic and fermented foods. *International Journal of Food Science and Technology*, 58(10): 4948-4964.

- Ilinskaya ON, Ulyanova VV, Yarullina DR and Gataullin IG, 2017. Secretome of intestinal Bacilli: a natural guard against pathologies. *Frontiers in Microbiology*, 8, p.1666.
- Jaimee G. and Halami PM, 2016. High level aminoglycoside resistance in *Enterococcus*, *Pediococcus* and *Lactobacillus* species from farm animals and commercial meat products. *Annals of Microbiology*, 66(1): 101-110.
- Jamal M, Shareef M and Sajid S, 2017. Lincomycin and tetracycline resistance in poultry. *Review. Matrix Science Pharmacology*, 1(1): 33-38.
- Jiang YH, Yang RS, Lin YC, Xin WG, Zhou HY, Wang F, Zhang QL and Lin LB, 2023. Assessment of the safety and probiotic characteristics of *Lactobacillus salivarius* CGMCC20700 based on whole-genome sequencing and phenotypic analysis. *Frontiers in Microbiology*, 14, p.1120263.
- Juricova H, Matiasovicova J, Kubasova T, Cejkova D and Rychlik I, 2021. The distribution of antibiotic resistance genes in chicken gut microbiota commensals. *Scientific Reports*, 11(1): 3290.
- Karapetkov N, Georgieva R, Rumyan N and Karaivanova E, 2011. Antibiotic susceptibility of different lactic acid bacteria strains. *Beneficial Microbes*, 2(4): 335-339.
- Kastner S, Perreten V, Bleuler H, Hugenschmidt G, Lacroix C and Meile L, 2006. Antibiotic susceptibility patterns and resistance genes of starter cultures and probiotic bacteria used in food. *Systematic and Applied Microbiology*, 29(2): 145-155.
- Kerek Á, Román I, Szabó Á, Pézsa NP. and Jerzsele Á, 2025. Antibiotic Resistance Gene Expression in Veterinary Probiotics: Two Sides of the Coin. *Veterinary Sciences*, 12(3): 217.
- Kerek A, Szabó E, Szabó Á, Papp M, Bányai K, Kardos G, Kaszab E, Bali K and Jerzsele Á, 2024. Investigating antimicrobial resistance genes in probiotic products for companion animals. *Frontiers in Veterinary Science*, 11, p.1464351.
- Khan I, Nawaz M, Anjum AA and Ahmad MUD, 2019. Isolation and in vitro Characterization of Anti-Salmonella Enteritidis Probiotic Potential of Indigenous Lactobacilli from Poultry. *Pakistan Veterinary Journal*, 39(4).
- Kim D, Kim S, Kwon Y, Kim Y, Park H, Kwak K, Lee H, Lee JH, Jang KM, Kim D and Lee S.H, 2023. Structural insights for β -lactam antibiotics. *Biomolecules & Therapeutics*, 31(2): 141.
- Kobayashi N, Alam MM, Nishimoto Y, Urasawa S, Uehara N and Watanabe N, 2001. Distribution of aminoglycoside resistance genes in recent clinical isolates of *Enterococcus faecalis*, *Enterococcus faecium* and *Enterococcus avium*. *Epidemiology & Infection*, 126(2): 197-204.
- Kumawat M, Nabi B, Daswani M, Viquar I, Pal N, Sharma P, Tiwari S, Sarma DK, Shubham S and Kumar M, 2023. Role of bacterial efflux pump proteins in antibiotic resistance across microbial species. *Microbial Pathogenesis*, 181, p.106182.
- Kwon JH and Powderly WG, 2021. The post-antibiotic era is here. *Science*, 373(6554): 471-471.
- Le QP, Ueda S, Nguyen TNH, Dao TVK, Van Hoang TA, Tran TTN, Hirai I, Nakayama T, Kawahara R, Do TH and Vien QM, 2015. Characteristics of extended-spectrum β -lactamase-producing *Escherichia coli* in retail meats and shrimp at a local market in Vietnam. *Foodborne pathogens and disease*, 12(8): 719-725.
- Ledina T, Mohar-Lorbeg P, Golob M, Djordjevic J, Bogovič-Matijašić B and Bulajić S, 2018. Tetracycline resistance in lactobacilli isolated from Serbian traditional raw milk cheeses. *Journal of Food Science and Technology*, 55(4): 1426-1434.
- Lee J, Kim, S. and Kang, C.H, 2022. Screening and probiotic properties of lactic acid bacteria with potential immunostimulatory activity isolated from kimchi. *Fermentation*, 9(1): 4.
- Lerner A, Matthias T. and Aminov R, 2017. Potential effects of horizontal gene exchange in the human gut. *Frontiers in Immunology*, 8, p.1630.
- Liu Y, Nawazish H, Farid MS, Abdul Qadoos K, Habiba UE, Muzamil M, Tanveer M, Sienkiewicz M, Lichota A and Łopusiewicz Ł, 2024. Health-promoting effects of *Lactobacillus acidophilus* and its technological applications in fermented food products and beverages. *Fermentation*, 10(8): 380.
- Ludfiani DD, Asmara W, Wahyuni AETH and Astuti P, 2021. Identification of *Lactobacillus* spp. on basis morphological, physiological, and biochemical characteristic from Jawa super chicken excreta. In *BIO Web of Conferences* (Vol. 33, p. 06012). EDP Sciences.
- Lungu IA, Moldovan OL, Biriş V. and Rusu A, 2022. Fluoroquinolones hybrid molecules as promising antibacterial agents in the fight against antibacterial resistance. *Pharmaceutics*, 14(8): 1749.
- Ma Q, Pei Z, Fang Z, Wang H, Zhu J, Lee YK, Zhang H, Zhao J, Lu W. and W, 2021. Evaluation of tetracycline resistance and determination of the tentative microbiological cutoff values in lactic acid bacterial species. *Microorganisms*, 9(10): 2128.
- Malhotra-Kumar S, Lammens C, Piessens J and Goossens H, 2005. Multiplex PCR for simultaneous detection of macrolide and tetracycline resistance determinants in streptococci. *Antimicrobial agents and chemotherapy*, 49(11): 4798-4800.
- Mandal A, Mandal RK, Yang Y, Khatri B, Kong BW and Kwon YM, 2021. In vitro characterization of chicken gut bacterial isolates for probiotic potentials. *Poultry Science*, 100(2): 1083-1092.
- Mejia-Caballero A. and Marco ML, 2025. Lactobacilli biology, applications and host interactions. *Nature Reviews Microbiology*, pp.1-16.
- Moghim B, Ghobadi Dana M, Shapouri R and Jalili M, 2023. Antibiotic resistance profile of indigenous *Streptococcus thermophilus* and *Lactobacillus bulgaricus* strains isolated from traditional yogurt. *Journal of Food Quality*, 2023(1): 4745784.
- Moravkova M, Kostovova I, Kavanova K, Pechar R, Stanek S, Brychta A, Zeman M and Kubasova T, 2022. Antibiotic susceptibility, resistance gene determinants and corresponding genomic regions in *Lactobacillus amylovorus* isolates derived from wild boars and domestic pigs. *Microorganisms*, 11(1): 103.
- Morawska LP and Kuipers OP, 2023. Cell-to-cell non-conjugative plasmid transfer between *Bacillus subtilis* and lactic acid bacteria. *Microbial Biotechnology*, 16(4): 784-798.
- Muñoz MDCC, Benomar N, Lerma LL, Gálvez A and Abriouel H, 2014. Antibiotic resistance of *Lactobacillus pentosus* and *Leuconostoc pseudomesenteroides* isolated from naturally-fermented Aloreña table olives throughout fermentation process. *International Journal of Food Microbiology*, 172, pp.110-118.
- Muteeb G, Rehman MT, Shahwan M and Aatif M, 2023. Origin of antibiotics and antibiotic resistance, and their impacts on drug development: A narrative review. *Pharmaceutics*, 16(11): 1615.
- Nawaz M, Wang J, Zhou A, Ma C, Wu X, Moore JE, Cherie Millar B and Xu J, 2011. Characterization and transfer of antibiotic resistance in lactic acid bacteria from fermented food products. *Current microbiology*, 62(3): 1081-1089.
- Obioha PI, Anyogu A, Awamaria B, Ghoddusi HB. and Ouoba LII, 2023. Antimicrobial resistance of lactic acid bacteria from Nono, a naturally fermented milk product. *Antibiotics*, 12(5): 843.

- Ojha AK, Shah NP. and Mishra V, 2021. Conjugal Transfer of Antibiotic Resistances in *Lactobacillus* spp. *Current Microbiology*, 78(8): 2839-2849.
- Ouoba LII, Lei V and Jensen LB, 2008. Resistance of potential probiotic lactic acid bacteria and bifidobacteria of African and European origin to antimicrobials: determination and transferability of the resistance genes to other bacteria. *International Journal of Food Microbiology*, 121(2): 217-224.
- Poornachandra Rao K, Chennappa G, Suraj U, Nagaraja H, Charith Raj AP. and Sreenivasa MY, 2015. Probiotic potential of *Lactobacillus* strains isolated from sorghum-based traditional fermented food. *Probiotics and Antimicrobial Proteins*, 7(2): 146-156.
- Poulton NC. and Rock JM, 2022. Unraveling the mechanisms of intrinsic drug resistance in *Mycobacterium tuberculosis*. *Frontiers in Cellular and Infection Microbiology*, 12, p.997283.
- Preethi C, Thumu SCR and Halami PM, 2017. Occurrence and distribution of multiple antibiotic-resistant *Enterococcus* and *Lactobacillus* spp. from Indian poultry: in vivo transferability of their erythromycin, tetracycline and vancomycin resistance. *Annals of Microbiology*, 67(6): 395-404.
- Rajoka MSR, Hayat HF, Sarwar S, Mehwish HM, Ahmad F, Hussain N, Shah SZH, Khurshid M, Siddiqui M and Shi J, 2018. Isolation and evaluation of probiotic potential of lactic acid bacteria isolated from poultry intestine. *Microbiology*, 87(1): 116-126.
- Rastogi S and Singh A, 2022. Gut microbiome and human health: Exploring how the probiotic genus *Lactobacillus* modulate immune responses. *Frontiers in Pharmacology*, 13, p.1042189.
- Refaat SS, Erdem ZA, Kasapoğlu MZ, Ortakçı F and Dertli E, 2025. Assessing the Antibiotic Resistance in Food Lactic Acid Bacteria: Risks in the Era of Widespread Probiotic Use. *Food Science & Nutrition*, 13(8): e70740.
- Rodríguez-Sánchez S, Ramos IM, Seseña S, Poveda JM and Palop ML, 2021. Potential of *Lactobacillus* strains for health-promotion and flavouring of fermented dairy foods. *LWT*, 143, p.111102.
- Rojo-Bezares B, Sáenz Y, Poeta P, Zarazaga M, Ruiz-Larrea F and Torres C, 2006. Assessment of antibiotic susceptibility within lactic acid bacteria strains isolated from wine. *International Journal of Food Microbiology*, 111(3): 234-240.
- Rokon-Uz-Zaman M, Bushra A, Pospo TA, Runa MA, Tasnuva S, Parvin MS and Islam MT, 2023. Detection of antimicrobial resistance genes in *Lactobacillus* spp. from poultry probiotic products and their horizontal transfer among *Escherichia coli*. *Veterinary and Animal Science*, 20, p.100292.
- Rosique RM, Chamignon C, Mhedbi-Hajri N, Chain F, Derrien M, Vazquez UE, Garault P, Cotillard A, Pham HP, Chervaux C and Humaran LB, 2019. The potential probiotic *Lactobacillus rhamnosus* CNCM 1-3690 strain protects the intestinal barrier by stimulating both mucus production and cytoprotective response. *Scientific Reports*, 9, pp.1-14.
- Rossi F, Amadoro C, Gasperi M and Colavita G, 2022. *Lactobacilli* infection case reports in the last three years and safety implications. *Nutrients*, 14(6): 1178.
- Rossi F, Rizzotti L, Felis GE and Torriani S, 2014. Horizontal gene transfer among microorganisms in food: current knowledge and future perspectives. *Food microbiology*, 42, pp.232-243.
- Rozman V, Lorbeg PM, Accetto T and Matijašić BB, 2020. Characterization of antimicrobial resistance in *Lactobacilli* and *Bifidobacteria* used as probiotics or starter cultures based on integration of phenotypic and in silico data. *International journal of Food Microbiology*, 314, p.108388.
- Rzepkowska A, Zielińska D, Oldak A. and Kołożyn-Krajewska D, 2017. Organic whey as a source of *Lactobacillus* strains with selected technological and antimicrobial properties. *International Journal of Food Science and Technology*, 52(9): 1983-1994.
- Saini K and Tomar SK, 2017. In vitro evaluation of probiotic potential of *Lactobacillus* cultures of human origin capable of selenium bioaccumulation. *Lwt*, 84, pp.497-504.
- Saleem N, Nawaz M, Ghafoor A, Javeed A, Mustafa A, Yousuf, MR and Khan I, 2018. Phenotypic and Molecular Analysis of Antibiotic Resistance in *Lactobacilli* of Poultry Origin from Lahore, Pakistan. *Pakistan Veterinary Journal*, 38(4).
- Salveti E, Harris HM, Felis GE and O'Toole PW, 2018. Comparative genomics of the genus *Lactobacillus* reveals robust phylogroups that provide the basis for reclassification. *Applied and Environmental Microbiology*, 84(17): e00993-18.
- Sandes S, Alvim L, Silva B, Acúrcio L, Santos C, Campos M, Santos C, Nicoli J, Neumann E and Nunes Á, 2017. Selection of new lactic acid bacteria strains bearing probiotic features from mucosal microbiota of healthy calves: Looking for immunobiotics through in vitro and in vivo approaches for immunoprophylaxis applications. *Microbiological Research*, 200, pp.1-13.
- Selim S, 2022. Mechanisms of gram-positive vancomycin resistance. *Biomedical Reports*, 16(1): 7.
- Seneviratne SASM, Weerasooriya PR and George D, 2023. Determination of the Acid Tolerance in *Lactobacillus* Isolated from Yogurt.
- Sengun IY, Kilic G, Charoenyingcharoen P, Yukphan P and Yamada Y, 2022. Investigation of the microbiota associated with traditionally produced fruit vinegars with focus on acetic acid bacteria and lactic acid bacteria. *Food Bioscience*, 47, p.101636.
- Seo H, Bae JH, Kim G, Kim SA, Ryu BH and Han NS, 2021. Suitability analysis of 17 probiotic type strains of lactic acid bacteria as starter for kimchi fermentation. *Foods*, 10(6): 1435.
- Seyirt S, Tezel BU and Şanlıbaba P, 2024. Identification and Antibiotic Resistance of *Lactobacillus* and *Bifidobacterium* Species from Manufactured Probiotic Dairy Products. *Journal of Food Processing and Preservation*, 2024(1): 1619353.
- Shao Y, Zhang W, Guo H, Pan L, Zhang H and Sun T, 2015. Comparative studies on antibiotic resistance in *Lactobacillus casei* and *Lactobacillus plantarum*. *Food Control*, 50, pp.250-258.
- Sharma P, Tomar SK, Goswami P, Sangwan V and Singh R, 2014. Antibiotic resistance among commercially available probiotics. *Food Research International*, 57, pp.176-195.
- Sharma P, Tomar SK, Sangwan V, Goswami P and Singh R, 2016. Antibiotic resistance of *Lactobacillus* sp. isolated from commercial probiotic preparations. *Journal of Food Safety*, 36(1): 38-51.
- Sirisopapong M, Shimosato T, Okrathok S and Khempaka S, 2023. Assessment of lactic acid bacteria isolated from the chicken digestive tract for potential use as poultry probiotics. *Animal Bioscience*, 36(8): 1209.
- Sivamaruthi BS, Alagarsamy K, Suganthi N, Thangaleela S, Kesika P and Chaiyasut C, 2022. The role and significance of *Bacillus* and *Lactobacillus* species in Thai fermented foods. *Fermentation*, 8(11): 635.
- Sorescu I, Dumitru M and Ciurescu G, 2021. *Lactobacillus* spp. strains isolation, identification, preservation and quantitative determinations from gut content of 45-day-old chickens broilers. *Brazilian Journal of Poultry Science*, 23(01): eRBCA-2020.
- Sornsene P, Singkhamanan K, Sangkhathat S, Saengsuwan P and Romyasmit C, 2021. Probiotic properties of *Lactobacillus* species isolated from fermented palm sap in

- Thailand. Probiotics and antimicrobial proteins, 13(4): 957-969.
- Stefanovic E, Fitzgerald G and McAuliffe O, 2017. Advances in the genomics and metabolomics of dairy lactobacilli: A review. *Food Microbiology*, 61, pp.33-49.
- Stefańska I, Kwiecień E, Józwiak-Piasecka K, Garbowska M, Binek M and Rzewuska M, 2021. Antimicrobial susceptibility of lactic acid bacteria strains of potential use as feed additives-the basic safety and usefulness criterion. *Frontiers in Veterinary Science*, 8, p.687071.
- Sun Z, Harris HM, McCann A, Guo C, Argimón S, Zhang W, Yang X, Jeffery IB, Cooney JC, Kagawa TF and Liu W, 2015. Expanding the biotechnology potential of lactobacilli through comparative genomics of 213 strains and associated genera. *Nature Communications*, 6(1): 8322.
- Sutcliffe J, Grebe T, Tait-Kamradt A and Wondrack L, 1996. Detection of erythromycin-resistant determinants by PCR. *Antimicrobial Agents and Chemotherapy*, 40(11): 2562-2566.
- Thumu SCR and Halami PM, 2019. Conjugal transfer of *erm* (B) and multiple *tet* genes from *Lactobacillus* spp. to bacterial pathogens in animal gut, in vitro and during food fermentation. *Food Research International*, 116, pp.1066-1075.
- THUY NP. and TRAINN, 2024. Screening of *Lactobacillus* from Noi chicken gut as potential probiotics against poultry pathogens. *Biodiversitas Journal of Biological Diversity*, 25(10).
- Tian Q, Ye H, Zhou X, Wang J, Zhang L, Sun W, Duan C, Fan M, Zhou W, Bi C and Ye Q, 2025. Evaluating the health risk of probiotic supplements from the perspective of antimicrobial resistance. *Microbiology Spectrum*, 13(1): e00019-24.
- Tsega KT, Maina KJ and Tesema NB, 2023. Characterization of potential probiotics *Lactobacillus* species isolated from the gastrointestinal tract of Rhode Island Red (RIR) chicken in Ethiopia. *Heliyon*, 9(7).
- Turkmen N, Akal C and Özer B, 2019. Probiotic dairy-based beverages: A review. *Journal of Functional Foods*, 53, pp.62-75.
- Vahabzadeh S and ÖZPINAR H, 2018. Investigation of some biochemical properties, antimicrobial activity and antibiotic resistances of kefir supernatants and *Lactococcus lactis* ssp. *lactis* strains isolated from raw cow milk and cheese samples. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi*, 24(3).
- Vakulenko SB and Mobashery S, 2003. Versatility of aminoglycosides and prospects for their future. *Clinical Microbiology Reviews*, 16(3): 430-450.
- Van Boeckel TP, Pires J, Silvester R, Zhao C, Song J, Criscuolo NG, Gilbert M, Bonhoeffer S and Laxminarayan R, 2019. Global trends in antimicrobial resistance in animals in low- and middle-income countries. *Science*, 365, p.eaaw 1944.
- Van Duinkerken E, Greko C, Pringle M, Baptiste KE, Catry B, Jukes H, Moreno MA, Pomba MCMF, Pyörälä S, Rantala M and Ružauskas M, 2014. Pleuromutilins: use in food-producing animals in the European Union, development of resistance and impact on human and animal health. *Journal of Antimicrobial Chemotherapy*, 69(8): 2022-2031.
- Vikesland P, Garner E, Gupta S, Kang S, Maile-Moskowitz A and Zhu NI, 2019. Differential drivers of antimicrobial resistance across the world. *Accounts of Chemical Research*, 52(4): 916-924.
- Von Wintersdorff CJ, Penders J, Van Niekerk JM, Mills ND, Majumder S, Van Alphen LB, Savelkoul PH and Wolffs PF, 2016. Dissemination of antimicrobial resistance in microbial ecosystems through horizontal gene transfer. *Frontiers in Microbiology*, 7, p.173.
- Wang Y, Lyu N, Liu F, Liu WJ, Bi Y, Zhang Z, Ma S, Cao J, Song X, Wang A, Zhang G, Hu Y, Zhu B, Gao GF. 2021. More diversified antibiotic resistance genes in chickens and workers of the live poultry markets. *Environ Int* 153:106534.
- Wang J, Li M, Liu M, Yang K, Zhang J, Fan M and Wei X, 2018. Antibiotic resistance of coagulase-negative staphylococci and lactic acid bacteria isolated from naturally fermented chinese cured beef. *Journal of Food Protection*, 81(12): 2054-2063.
- Wang K, Zhang H, Feng J, Ma L, de la Fuente-Núñez C, Wang S and Lu X, 2019. Antibiotic resistance of lactic acid bacteria isolated from dairy products in Tianjin, China. *Journal of Agriculture and Food Research*, 1, p.100006.
- Xu J, Wang H, Xu R, Li Q, Li L, Su Y, Liu J and Zhu W, 2024. Daily fluctuation of *Lactobacillus* species and their antibiotic resistance in the colon of growing pigs. *Science of The Total Environment*, 918, p.170821.
- Yang X, Hu W, Xiu Z, Jiang A, Yang X, Ji Y, Guan Y and Feng K, 2020. Comparison of northeast sauerkraut fermentation between single lactic acid bacteria strains and traditional fermentation. *Food Research International*, 137, p.109553.
- Yao P, Mohd Esah E and Zhao C, 2025. Regulatory mechanisms and applications of *Lactobacillus* biofilms in the food industry. *Frontiers in Microbiology*, 15, pp.1465373.
- Zarzecka U, Chajęcka-Wierchowska W. and Zadernowska A, 2022. Microorganisms from starter and protective cultures-Occurrence of antibiotic resistance and conjugal transfer of *tet* genes in vitro and during food fermentation. *Lwt*, 153, pp.112490.
- Zavišić G, Popović M, Stojkov S, Medić D, Gusman V, Jovanović Lješković N and Jovanović Galović A, 2023. Antibiotic resistance and probiotics: knowledge gaps, market overview and preliminary screening. *Antibiotics*, 12(8): 1281.
- Zheng J, Ruan L, Sun M and Gänzle M, 2015. A genomic view of *Lactobacilli* and *pediococci* demonstrates that phylogeny matches ecology and physiology. *Applied and Environmental Microbiology*, 81(20): 7233-7243.
- Zheng J, Van der Meeren P and Sun W, 2024. New insights into protein-polysaccharide complex coacervation: Dynamics, molecular parameters, and applications. *Aggregate*, 5(1): e449.
- Zheng J, Wittouck S, Salvetti E, Franz CM, Harris HM, Mattarelli P, O'toole PW, Pot B, Vandamme P, Walter J and Watanabe K, 2020. A taxonomic note on the genus *Lactobacillus*: Description of 23 novel genera, emended description of the genus *Lactobacillus* Beijerinck 1901, and union of *Lactobacillaceae* and *Leuconostocaceae*. *International journal of Systematic and Evolutionary Microbiology*, 70(4): 2782-2858.
- Zhou JS, Pillidge CJ, Gopal PK and Gill HS, 2005. Antibiotic susceptibility profiles of new probiotic *Lactobacillus* and *Bifidobacterium* strains. *International journal of food microbiology*, 98(2): 211-217.
- Zielińska D and Kolożyn-Krajewska D, 2018. Food-origin lactic acid bacteria may exhibit probiotic properties. *BioMed Research International*, 2018(1): 5063185.
- Zolfaghari SI and Amin M, 2025. Identification, molecular diversity, phylogenetic analysis, and antimicrobial activity of *Lactobacilli* isolated from buffalo raw milk. *International Dairy Journal*, p.106278.
- Zommiti M, Chikindas ML and Ferchichi M, 2020. Probiotics—live biotherapeutics: a story of success, limitations, and future prospects—not only for humans. *Probiotics and antimicrobial proteins*, 12(3): 1266-1289.
- Zou X, Weng M, Ji X, Guo R, Zheng W and Yao W, 2017. Comparison of antibiotic resistance and copper tolerance of *Enterococcus* spp. and *Lactobacillus* spp. isolated from piglets before and after weaning. *Journal of Microbiology*, 55(9): 703-710.